NAIC-ID(RS)T-0255-95

# NATIONAL AIR INTELLIGENCE CENTER

CHINESE LARGE SCALE ASTRONOMICAL AND SPACE TELESCOPE DEVELOPMENT

by

Ma Pinzhong

## HUMAN TRANSLATION

NAIC-ID(RS)T-0255-95 11 September 1995

MICROFICHE NR: 95C000568

CHINESE LARGE SCALE ASTRONOMICAL AND SPACE TELESCOPE DEVELOPMENT

By: Ma Pinzhong

English pages: 15

Source: Wo Guo Da Xing Tian Wen Yu Kong Jian Wang Yuan
Jin G1993 No. 12; pp. 7-10

Country of origin: China
Translated by: SCITRAN
F33657-84-D-0165
Requester: NAIC/TASC/Lt Shaun M. McMahon
Approved for public release: distribution unlimited.

| | |
|---|---|
| THIS TRANSLATION IS A RENDITION OF THE ORIGINAL FOREIGN TEXT WITHOUT ANY ANALYTICAL OR EDITORIAL COMMENT STATEMENTS OR THEORIES ADVOCATED OR IMPLIED ARE THOSE OF THE SOURCE AND DO NOT NECESSARILY REFLECT THE POSITION OR OPINION OF THE NATIONAL AIR INTELLIGENCE CENTER. | PREPARED BY:<br><br>TRANSLATION SERVICES<br>NATIONAL AIR INTELLIGENCE CENTER<br>WPAFB, OHIO |

## GRAPHICS DISCLAIMER

All figures, graphics, tables, equations, etc. merged into this translation were extracted from the best quality copy available.

| Accesion For | |
|---|---|
| NTIS CRA&I | ☒ |
| DTIC TAB | ☐ |
| Unannounced | ☐ |
| Justification | |
| By | |
| Distribution / | |
| Availability Codes | |
| Dist | Avail and / or Special |
| A-1 | |

Developing the utilization of space, exploring whether or not mankind can carry out mining on such celestial bodies as the moon, Mars, and so on, production without gravity and without pollution, the establishment of astronavigational launching pads free of gravity and astronomical observation stations without atmospheric turbulence; whether or not it is possible to make use of the huge amounts of energy bursting out from celestial bodies, and, in conjunction with that, research the energy production mechanisms in order to supply mankind with a new energy source; detailed study of the material make up of celestial bodies, as well as configuration, size, chemical and physical properties and their coordinates and movements, further research on the formation and evolution of star systems and stars, researching changes in the earth as well as their dangers for mankind, and so on--all these are problems celestial physicists, astrogeodesists, space astronomers, and astronavigation specialists are anxiously awaiting answers for. This then requires constantly raising light gathering capabilities in order to observe celestial bodies and star systems which are darker, smaller, and farther away; constantly raising resolution in order to study the fine structures of celestial bodies in more detail so as to facilitate high accuracy measurements of the positions and movements of celestial bodies and physical parameters such as the brightnesses and optical spectra associated with celestial bodies, temperatures, masses, magnetic fields, and so on, and, in conjunction with this, having a simultaneous view toward the tracking and survey of large spacecraft

---

* Numbers in margins indicate foreign pagination. Commas in numbers indicate decimals.

after launch. To this end, various nations are all in mutual competition to develop large telescopes. For example, the U.S. has invested several billion U.S. dollars to set up two 10 meter and five 8 meter mirrors. The European Southern observatory set up four 8 meter mirrors. Great Britain and Japan each set up one 8 meter mirror. This even goes to the point of India, after completing 2.34 meter mirrors, also preparing to build one 7 meter mirror. These telescopes will all be built before the year 2000.

China, more than 2000 years ago, already discovered using the ancient Chinese sundial in order to observe the sun. Later, discoveries were also made of horizon, equatorial, and ecliptic theodolites, quadrants, abridged armilla, armillary spheres, and celestial globes. After liberation as well, there was successful development of 2.16 meter and 1.56 meter telescopes. However, compared to other countries in the competition to develop large model telescopes, China has already fallen behind in this area. This is very much out of character with China's position as a great nation. In order to develop China's astronomical and astronavigation activities and to make observations contributing to united world organizations, a type of plan was put forward to build one 4.3 meter optical infrared telescope in the year 2000, and, after that, with Beijing observatory's 2.16 meter telescope tied in together use optical interference to reach over 10 meter aperture resolutions. As far as this type of optical composite aperture telescope design--as shown in Fig.1 and Fig.2--is concerned, construction costs are low, construction periods are short, and they are capable of relatively quickly reaching advanced international levels.

/8

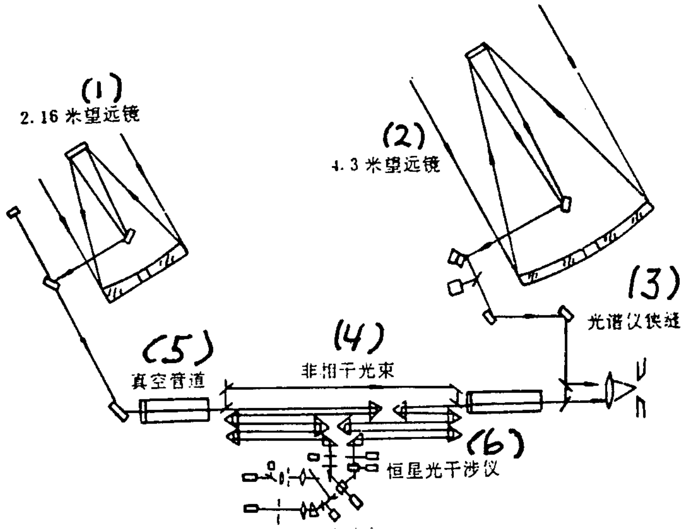


Fig.1 Principles of Star Light Interferometer and Noncoherent Light Gathering Systems

Key: (1) 2.16 Meter Telescope (2) 4.3 Meter Telescopes (3) Light Spectrometer Slit (4) Noncoherent Light Beam (5) Vacuum Conduit (6) Star Light Interferometer

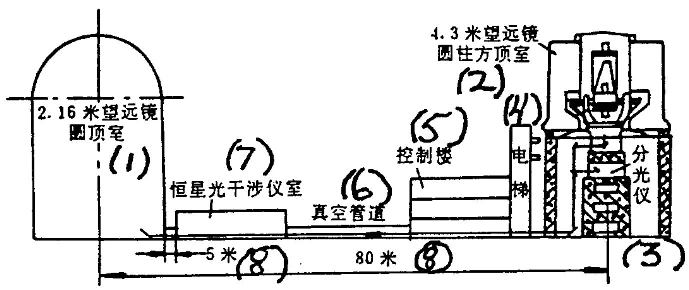


Fig.2 Optical Composite Aperture Telescope Observatory

Key: (1) 2.16 Meter Telescope Dome Chamber (2) 4.3 Meter Telescope Square Cylinder Top Chamber (3) Spectroscope (4) Elevator (5) Control Building (6) Vacuum Conduit (7) Star Light Interferometer Chamber (8) Meter

各国已完成的单镜面 3.5 米口径以上望远镜一览表

| (1) 序号 | (2) 口径 | 名称 (3) | 国别 (4) | 台址 (5) | 型式 (6) | (7) 主焦比 | (8) 完成日期 |
|---|---|---|---|---|---|---|---|
| 1 | 6 米 (9) | Special Str Obs. T. | 苏 (10) | Zelenchuk | (19) 地平式 (18) | f/4 | 1976 年 (22) |
| 2 | 5 米 | Hale | 美 (11) | Mt. Palomar | 赤道马蹄式 | f/3.3 | 1949 年 |
| 3 | 4.2 米 | WHT | 英 (12) | La Palma | 地平式 (18) | f/2.5 | 1987 年 |
| 4 | 4 米 | CTIO | 美 (11) | Cerro Tololo | (19) 赤道马蹄式 | f/2.8 | 1974 年 |
| 5 | 4 米 | KPNO | 美 (11) | Kitt Peak | (19) 赤道马蹄式 | f/2.8 | 1973 年 |
| 6 | 3.9 米 | AAT | 英澳 (13) | Siding Spring | (19) 赤道马蹄式 | f/3.3 | 1974 年 |
| 7 | 3.8 米 | UKIRT | 英 (12) | Mauna Kea | (20) 赤道轭式 | f/2.5 | 1980 年 |
| 8 | 3.6 米 | CFHT | 加拿大,法国,美(夏威夷) (14) | Mauna Kea | (21) 赤道式 | f/3.8 | 1979 年 |
| 9 | 3.6 米 | ESO | 欧共体 (15) | La Silla | (21) 赤道式 | f/3 | 1976 年 |
| 10 | 3.5 米 | MPI | 德,西班牙 (16) | Calar Alto | (21) 赤道式 | f/3.5 | 1986 年 |
| 11 | 3.5 米 | NTT | 欧共体 (17) | ESO, La Silla | (19) 地平式 | f/2.2 | 1988 年 |

(Page 8 Upper Left) Display of Telescopes Various Nations Have Already Completed with Single Mirror 3.5 Meter Apertures or More

Key: (1) Serial No. (2) Aperture (3) Nomenclature (4) Nationality (5) Location (6) Type (7) Main Focal Ratio (8) Completion Date (9) Meter (10) Soviet (11) U.S. (12) U.K. (13) Anglo-Australian (14) Canada, France, U.S. (Hawaii) (15) E.E.C. (16) Germany Spain (17) E.E.C. (18) Horizontal (19) Equatorial Horseshoe Type (20) Equatorial Yoke (21) Equatorial (22) Year

## I. New 4.3 Meter Optical Infrared Technology Telescope Design Plans

At the present time, various countries have already completed telescopes with single mirror apertures of 3.5 meters or above as shown in the Table. As a result, if China also develops 3.5 meter mirrors, then, our position in the international astronomical world is too low. If we develop 4.3 meter mirrors, we will then be able to clearly raise China's astronomical position. Moreover, the capability exists to design and develop this successfully. The reason is that--if 6 meter or 8 meter mirrors are built--mirror blanks then become a problem. Moreover, there are no appropriate sites, and there are difficulties in all the areas of finances, equipment, as well as technology. Also, the microcrystalline glass of a 4.3 meter curved moon shaped thin main mirror weighs 3.7 tons. It is possible to use the melting furnace of the Xinhu Glass Plant to renovate the original 2.16 meter mirror to produce it. It is also possible to place an order with the Russians. Moreover, 4.3 meter mirror development conditions are already basically in hand. In conjunction with that, it is possible to install it at Xinglong observatory. In this way, there is then a capability to strive for completion of construction in the year 2000.

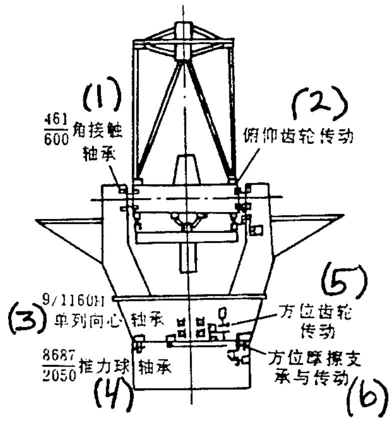


Fig.3 4.3 Meter Optical Infrared Telescope

Key: (1) Angular Contact Bearing (2) Pitch Gear Drive (3) Single Row Centripetal Bearing (4) Thrust Ball Bearings (5) Directional Gear Drive (6) Directional Friction Support and Drive

Due to horizontal type telescopes possessing the flaws of large volumes, bulkiness, crowding in domes, high construction costs, and so on, as far as 4.3 meter mirrors are concerned, it was determined to opt for the use of Fig.3's flat structure. It is a kind of symmetrical structural form. The stressing situation is good. The structure is simple. Volumes are small. Weights are light. Construction costs are low. There are also two resistant focal points associated with instruments of expandable weight and large volumes. In order to complete all the operations associated with celestial physics, the requirements of astrogeodesy, space astronomy, and astronavigation are considered at the same time. In particular, numerous focal points and multi use systems were designed as shown in Fig.4. The systems in question opt for the use of main focal ratios f/2 and focal resistant ratio f/13 associated with high light gathering capacity R-C Kasaigelin (phonetic) systems. Use is made of 3 piece correctable mirrors in order to increase image quality. The viewing field is 1°. A 10 cm thick crescent

moon shape thin main mirror uses an active optical measurement and control system to raise image quality. Main focal points are capable of detecting celestial objects in large viewing fields extremely far away and extremely dark and weak. In order to raise instrument utilization rates, observation wave bands are taken and expanded to 15 microns to do infrared sky patrol and space monitoring, infrared star maps, brightness measurements of dark sources, and spectrum analyses. In conjunction with that, it is possible to make observations in daylight or bright moon light. It is set up to have an f/15 calorie focus system. The first resistant focus sets up a 97 unit self-adjusting compensating deformation mirror and a Shack-Hartmann wave front detector. It is capable, in the 1.5-15 micron area of making observations of high resolution precision structure imagery approaching extreme seeing limits. The focal ratio is f/13. The second resistant focus sets up a CCD camera as well as a guiding star system, a TV monitored control, photon counter, multitarget multioptical fiber spectrograph, as well as high resolution optical spectrometer, and so on. There are systems to quickly, accurately, and conveniently replace ancillary instruments. f/35 refractive focus systems are capable of making relatively bright star imagery observations and measurements such as high chromatic dispersion and high resolution spectra, luminosity, and so on. Through vacuum conduit, over 10 meter aperture resolutions are reached with 2.16 meter mirror connection device optical interference. In order to make it easy for large fields of view to sweep the sky, on the sides of the middle piece, there is installed a 15cm star seeking mirror. The focus ratio is f/5. The field of view is 4°. The power is 40x.

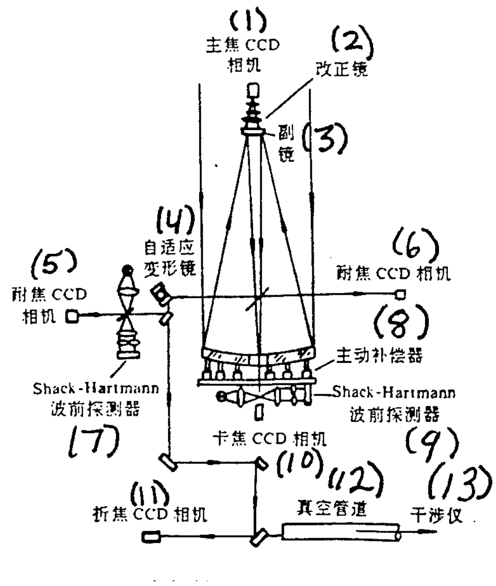


Fig.4 4.3 Meter Optical Infrared Optical Telescope System

Key: (1) Main Focus CCD Camera (2) Correction Mirror (3) Secondary Mirror (4) Self-Adjusting Deformation Mirror (5) Resistant Focus CCD Camera (6) Resistant Focus CCD Camera (7) Shack- Hartmann Wave Front Detector (8) Active Compensation Device (9) Shack-Hartmann Wave Front Detector (10) Blocking Focus CCD Camera (11) Refractive Focus CCD Camera (12) Vacuum Conduit (13) Interferometer

/9

As far as the telescope tube is concerned, option is made for welded trusses of Serrureier triangular seamless steel tubing associated with wide open equal curvature designs. When there is a requirement for the mirror tube to point to some arbitrary position, the relative curvature between the main and secondary mirrors < 0.03 microns. The relative inclination is < 2 minutes. Replacement of secondary mirrors uses localized change over of the secondary mirror cage as shown in Fig.5. When using a refractive focus, the secondary mirror cage is turned 180° to

make the refractive focus secondary mirror point down. When using infrared blocking focus, the infrared secondary mirror cage is put on. Use is made of linear force moment electric motors to do 4 minute oscillations at 10-20 Hz oscillation frequency. When using the main mirror, the secondary mirror cage is taken down. Secondary mirrors use gas cushions to act as side supports using vacuum suction pads fixed to the back. Using gears and racks 30cm foci adjustments are made using grating measurements to carry out dimensional control. CCD and dry plate cameras can be switched for each other. Secondary mirror chambers use four offset wing beams as supports.

The crescent moon shaped 10cm thick main mirror weighs 3.7 tons. It is supported on 68 active optical compensation devices. As shown in Fig.6., it is possible to measure and control surface shape to a precision $< \lambda/20$. The bottom surface of the main mirror has Shack-Hartmann wave front detectors. The upper end has safety limit position plates. The center has a fixed steel sleeve. The bottom surface of the main mirror and the side surfaces are painted with heat insulation adiabatic layers. The middle piece has 8 open type main mirror covers. The center has reflector mirrors and stops associated with two high speed replacement resistance foci and refractive foci light paths. Four offset wing beams are used as supports.

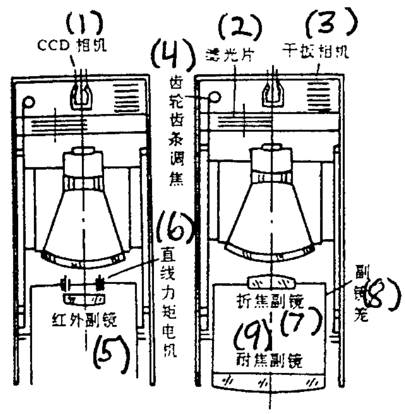


Fig.5 Secondary Lens Chamber Structure Diagram

Key: (1) CCD Camera (2) Optical Filter Chips (3) Dry Plate Camera (4) Gear and Rack Focus Adjustment (5) Infrared Secondary Mirror (6) Linear Force Moment Electric Devices (7) Refractive Focus Secondary Mirror (8) Secondary Mirror Cage (9) Resistant Focus Secondary Mirror

As far as high rigidity pedestal frames, as shown in Fig.3, are concerned, through mirror tubes supporting 40 ton weights on a horizontal axis, axial necks with 600mm diameters use 461/600 diagonal contact ball bearings to support radial and axial bearings. The structure is compact. Cleanliness is higher than with hydraulic bearings. Vertical axis systems support a weight of 120 tons. Use is made of 8687/2050 thrust ball bearings to support weights of 80 tons. The rest of the weight is driven, in conjunction with that, by 12 sets of friction wheel elastic supports. Radially, use is made of two 9/1160H single row centripetal ball bearing positions. There are level adjustment structures.

In order to guarantee that mirror tubes are able to accurately and rapidly aim at any star in half the sky, and, in conjunction with that, track it accurately, it is necessary to be able to quickly, slowly, slightly, and permanently move. It requires that twisting tubes be capable of pitches of 0 - 95°. Azimuths are ±270°. Turning and tracking speeds are 0 - 5°/sec. Accelerations are 0 - 0.5°/sec2 . Pitch uses grade 5 precision column straight gears associated with m = 5.Z1 = 480.Z2 = 24 and paired with an m = 3,i=20/40x20/40 speed reduction box. Directional friction drive uses 5.4 meter diameter friction plates and friction wheels with diameters of 200mm paired with a 3,i = 20/40x20/80 speed reduction box. Use is made of 250LYR-C1 model digital broad speed adjustment direct current force moment electrical device - speed measurement device sets to drive. In order to eliminate electrical devices where gear gaps set up counter moments of force (capable at high speeds of assisting movement in positive directions), use is made of a highly stable direct current power source to supply electricity.

Real time operation control systems are capable of being fully automatic, semiautomatic, or manually operated. Astronomers and experts in astronavigation are capable, on their

own laboratory television screens--through remote control synchronous satellite observations--of composing observation programs, automatically optimizing various types of parameters, carrying out data processing on observation results, analyzing, inferring, and making policy. In order to guarantee operational reliability and low cost, option was made for the use of multiple micro computers to carry out parallel control of systems doing the operations set out below:

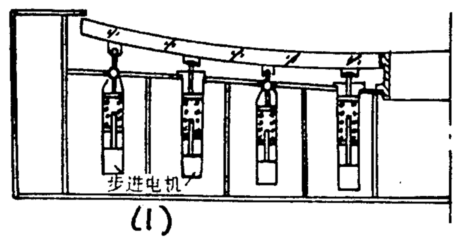


Fig.6 4.3 Meter Crescent Moon Shaped Main Mirror and Active Optical Compensation Device Chamber

Key: (1) Stepped Electrical Devices

1) operation, monitoring, control, and display; 2) direction, tracking control, configuration monitoring; 3) CCD imagery collection, processing, and recording; 4) active and self-adjusting optical measurement and control; 5) synchronous satellite digital code transmission remote control observations; 6) optical interference system light axis parallel and course deviation compensation measurement and control, signal reception and processing, and so on.

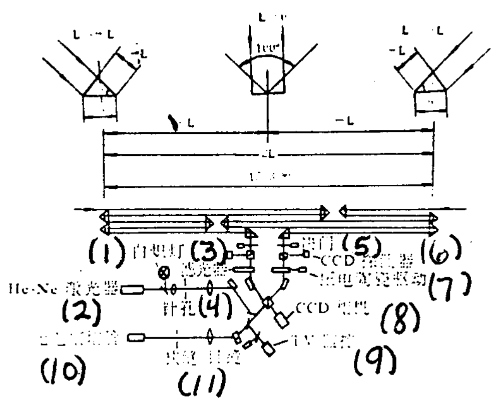


Fig.7 Star Light Interference System Light Path Diagram

Key: (1) Incandescent Lamp (2) He-Ne Laser (3) Light Filter Device (4) Pin Hole (5) Shutter (6) CCD [Illegible] (7) Piezoelectric Ceramic Drive (8) CCD Camera (9) TV Monitor Control (10) [Illegible] Tube (11) [Illegible] Eyepiece

## II. Star Light Interference System Design Plans

In order to reduce the influences of stray light and atmospheric turbulence, lower construction costs, and facilitate the construction of an interferometer chamber built on a good base, resistant to earthquakes, and with a constant temperature, a small volume interferometer as shown in Fig.7 was designed. In order to achieve interference with equal light strengths, the interferometer chamber in Fig.2 is far away from the 4.3 meter mirror, making the image forming light beams attenuate. /10 Moreover, use is made of stops for regulation, making light strengths equal to the 2.16 meter mirror in order to raise the

contrast of interference bands. Use is made of reflection type corner prisms in order to make quadruple reflections, causing course error compensation lengths to shrink to $L = b \times \cos\theta/m = 80 \times \cos 40°/4 = 15.3m$. Here, one assumes that the baseline distance between the two telescopes is b = 80m. Using cylindrical guides and step motor driven friction wheels with 50mm diameters, with guide stars, prism frame movement speeds V1 = 300mm/sec. When tracking fixed stars, V2 = 329 microns/sec. Micro adjustments of path errors use piezoelectric ceramic drive light wedges. The micro adjustment rate is 0.018 microns, satisfying the requirements of $\lambda/10$ path deviation compensation. Path deviation measurements use dual frequency laser interferometers. 0.2 minute light axis parallelism--besides requiring that the two telescopes do synchronous tracking of a star being measured--uses piezoelectric ceramic drive orthogonal prisms for compensation. Due to the striation bands of the two beams of coherent light including information on surface strength distributions of heavenly bodies, as a result, from the amplitudes of the band patterns and phases, it is possible to measure out such celestial body parameters as the positions of stars, angular diameters, the distances between double stars, and so on.

## III. Conclusions

With the support of experts and leaders in the fields of astronomy, astronavigation, and engineering technology from all over the country and under the direct leadership of the national science committee and the Academia Sinica, working through the All China Association and on the foundation of unity and mutual trust, efforts are exerted in common. China's 4.3 meter optical infrared telescope can be finished in the year 2000. After that, moreover, connecting machines to the 2.16 meter mirror, it makes light interference reach over 10 meter aperture resolutions,

achieving synchronous development with the large model telescopes of various nations of the world as well as synchronous research into the great achievements of the whole world in the subjects of astronomy and astronavigation, thereby raising China's international position and high technology level.

## DISTRIBUTION LIST

### DISTRIBUTION DIRECT TO RECIPIENT

| ORGANIZATION | MICROFICHE |
| --- | --- |
| B085 DIA/RTS-2FI | 1 |
| C509 BALLOC509 BALLISTIC RES LAB | 1 |
| C510 R&T LABS/AVEADCOM | 1 |
| C513 ARRADCOM | 1 |
| C535 AVRADCOM/TSARCOM | 1 |
| C539 TRASANA | 1 |
| Q592 FSTC | 4 |
| Q619 MSIC REDSTONE | 1 |
| Q008 NTIC | 1 |
| Q043 AFMIC-IS | 1 |
| E404 AEDC/DOF | 1 |
| E410 AFDTC/IN | 1 |
| E429 SD/IND | 1 |
| P005 DOE/ISA/DDI | 1 |
| 1051 AFIT/LDE | 1 |
| P090 NSA/CDB | 1 |

Microfiche Nbr: FTD95C000568
NAIC-ID(RS)T-0255-95